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Heavy Metals Evaluationin Some Soils of Egypt by Using Pollution Indices and Chemical Fractionation Technique

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Abstract

Background: The present research work was carried out to evaluate the soil content of some heavy elements in El-Fayoum Governorate, Egypt, and its contaminates environmental risks through pollution application and technique of chemical fractionation.

Materials and Methods: To fulfill these objectives, fifty soil samples were taken from surface soil a depth 0-30 cm to measure the concentration of Cd, Pb and Nimetals, and some soil characteristics on the other hand, pollution indices and fractionation technique were used .

Results: Results exhibited a diversity variation in the content of heavy metals content in El-Fayoum district compared with Tamyahdistrict.The % distributions of heavy metals were occupied enclosed, 45%, 36%, and 21%, for cadmium, lead, and nickel, respectively. Also, several factors were used to evaluate the degree of soil pollution like I-geo Index which showed that nickel > lead > cadmium; also, Contamination Factor followed this order: nickel >cadmium >lead. Enrichment factor revealed following order: cadmium >lead>nickel, and the soil sequential extraction of heavy metal fractions indicated the following order: Cd (F2> F5 > F1 > F3 > F4), Ni (F4> F5 > F3 > F2 > F1), and Pb (F5 > F2 >F1 > F4>F3).

Keywords: Heavy Metals, Pollution Indices, Chemical Fractionation, Soil contamination, conservation agriculture, Egypt.

INTRODUCTION

Egypt is one of the agricultural countries that relies generally on the deposition soil of Nile, so cumulate of heavy metals insoils a significant issue **Kheirallah and El-Samad,(2019).**This problem can lead to direct harm from pollutants or indirect harm from disruptions in the food chain (**Hu et al., 2017)**.As aresults of several activities such as uses of fertilizers, traffic emissions, pesticides,industrial chemicals and effluents, has led to an increase in pollution from metals likelead (Pb) cadmium (Cd), nickel (Ni), in the last decades **Chibuike and Obiora, (2022)**.

Soils are the prime source of heavy metals for crops and vegetables,Plants absorb these metals through their roots and transport them to other parts of the plant. On the other hand, sustainable agriculture is a way to preserve soil fertility and product quality. According to **Ansari *et al.*, (2022)**higher levels of heavy metals in soil can negatively impact crop yields and product quality, leading to a decrease in plant productivity by 20% or more(**Qin *et al.*, 2022).** On the other hand, increasing heavy metals contain affect growth and food safety of plant **(EL-Hassanin*et al*., 2020).**

The analyses of soil heavy metalscan provide valuable informationabout contamination and accumulation of heavy metals in the soil and the understanding of rhizosphere ecosystem quality **(Dar *et al.*, 2022)**. Heavy metals can exist in various forms in soil,such ascomprehensive soluble or exchangeable, combined with Iron/manganese oxides, combined with organic matter and combined with mineral fractions (residual**) (Nemati*et al*,. 2011).**

As results of the previous, The United Nations Assembly adopted a decree UNEA-3, to manage and address soil pollution. This signifies that soil pollution has now become a global concern in order to mitigate the impacts of this significant threat. (**Rodríguez-Eugenio *et al.*2018).** By virtue ofUnited Nations Assembly decree several researchers in different parts of world such as **Solgi*et al.*,(2012),** investigated Iranian soilpollution and observed that most of contaminated areas by cadmium wereindustrial areas andaboveworld critical limit. Also**Huang *et al.*, (2019)**examined heavy metal pollution in Chinese agricultural soil and foundthathighest polluted exceeded the permissible global limitswith cadmium and mercury.While**Salman *et al.*, (2018)** noted that the concentration of heavy metals in some Soil in the Southwest Giza were above the average levels of these metals in world soils.These studies further emphasize the widespread nature of soil pollution and its detrimental effects on both industrial and agricultural areas.

The main objective of this work aimed at determining and evaluating the risks of heavy metals contaminates (Cd, Ni and Pb) through the of pollution application and technique ofchemical fractionation in El-Fayoum and Tamyah districts, El-Fayoum Governorate, Egypt

Materials and Methods

Study area

El-Fayoum Governorate is located in the Western part of Egypt about 90 kilometers away of Cairo Governorate **Figure01,** with an area covers 6068 km^2, and 324000 fedans (136.1hectares) are the total cultivated areaand connected to Nile River with Bahr Yousef which delivered Nile water to it**El Zeiny and Effat(2017).**

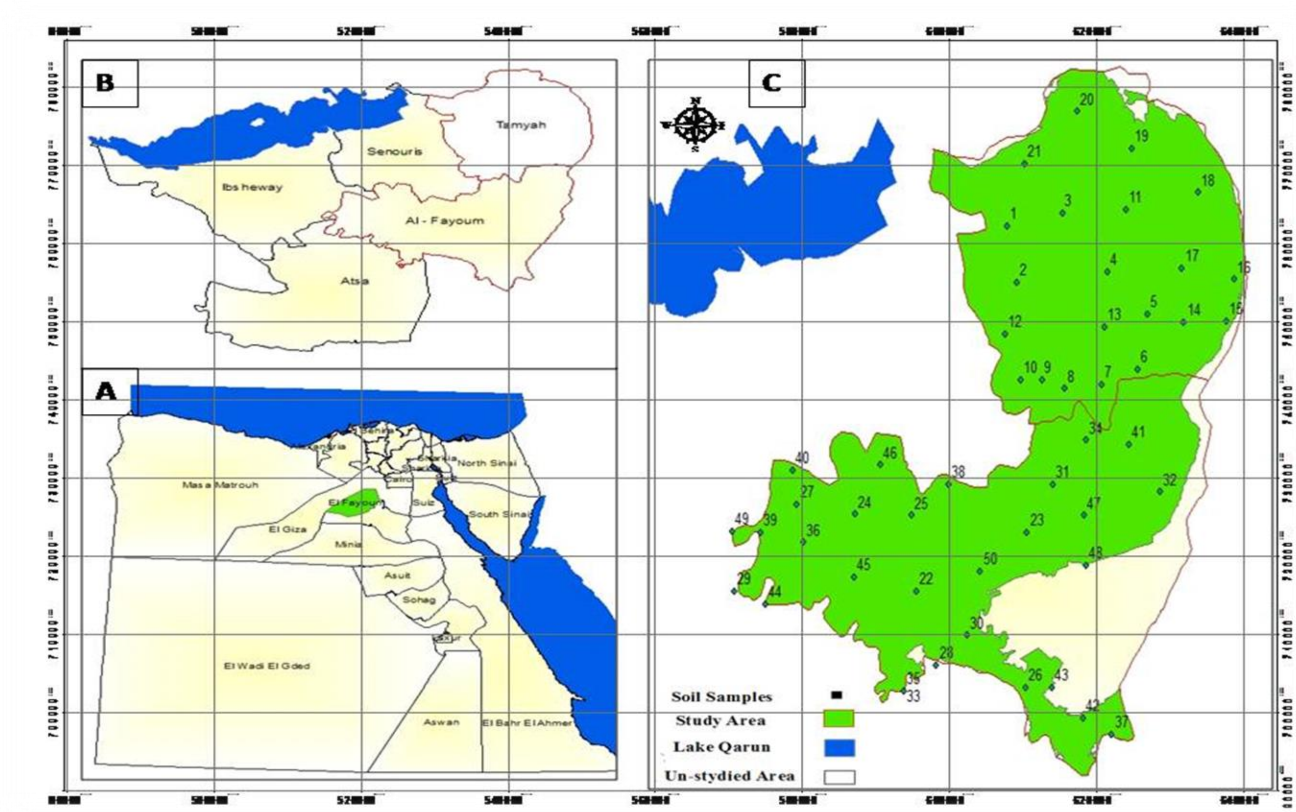

Figure 01: A El-Fayoum Governorate Location according to Egyptian Governorates map, **B** administrative classification of El-Fayoum Governorate include study area, **C** distribution of selected soil samplesin bothAl-Fayoum district and Tamyah district

Sampling and analyses

The current work includes two districts; Al-Fayoum district and Tamyah district, where fifty soil samples were taken from the soil a depth (0-30 cm)to measure the concentrations of cadmium, leadand nickelmetals.Distancesamong sampling sites were approximately 1.5 km. The exact latitude and longitude sitesof the sampling point was determined by GPS. **Figure01.** The collected soil samplingwere dried,lightly crushed, and passed through a 2 mm sieve to obtain fine soil. Then, soil heavy metals were determined

Soil **EC** was determined by conductor meter apparatus.Identifying Soil pH at 1: 2.5 ratios,water: soil suspensions. Calcium carbonate percentage ($CaCO_3$%) determined by using Scheibler'scalcimeter**,**to identify the percentage of organic matter Walkley and Black method was applied **FAO, (2020a, 2020b, 2020c)**.

Heavy metals concentrations were identifiedby method microwave digests of soil samples added with suprapure HNO_3/$HClO_4$/HCl, 5:1:1 v/v. **FAO, (2022)**.

Soil heavy metals fractionationwasmeasuredusing 1 gsoil: 40 ml of polycarbonate according to **Tissier*et al.*(1979)**to classified heavy metals into:exchangeable (F1) was extracted with magnesium chloride, carbonate (F2) was extracted with sodium acetate,oxidizable (F3) combined with organic matteras extracted with nitricacid/hydrogen peroxide/ammonium acetate,reducible (F4) combined with Iron /Manganise oxides was extractedwith hydroxylamine hydrochloride/acetic acidandresidual fraction (F5) was extracted with hydrochloric/perchloric acids.

Pollutant impact estimating methods

The pattern of metal pollution was calculated using Geo-accumulation index, Contamination and Enrichment Factors and Risk Assessment Code, which applied to estimate the impacts of heavy metals toxicity.

The Geo-accumulation index (Igeo)

The Geo-accumulation index (Igeo)has proven to be a valuable tool in predicting soil pollution,it has been utilized by manyresearchers as **Zheng *et al.*, (2018)** and **Zhao *et al.*, (2022),** to assess the extent of metal pollution in an area by comparing current metal concentrations with pre-existing levels.This index is based on the equation developed by **Muller, (1981)**:

$$\mathbf{Igeo} = \log_2 \frac{C_n}{1.5\ B_n} \quad (\mathbf{Eq.\ 1})$$

Where; ***Igeo*** *is the Geo-accumulation index,* C_n *is element concentrate in sample and Biogeochemical background value provided by* **Liao and Chao, (2004)**, *a constant of* ***1.5****helps to analyze natural fluctuationsin given substance content and minimal anthropogenic influences and* B_n *isbackground value.*

Buccolieri*et al.* (2006) has classified classes of Igeowere given in **Table 01**.

Table 01: Levels of contamination class values.

Class	Value	Soil dust quality
0	Igeo≤0	Un.C
1	0<Igeo<1	Un.C-M.C
2	1<Igeo<2	M.C
3	2<Igeo<3	M.C-S.C
4	3<Igeo<4	S.C
5	4<Igeo<5	S.C-E.C
6	Igeo≥5	E.C

Igeo: the index of Geo-accumulation;**Un.C**: Uncontaminate;**Un.C-M.C**: Un-contaminate -Moderate contaminate;**M.C**:Moderate contaminate;**M.C-S.C**: Moderate contaminate -strong contaminate; **S.C**: strong contaminate; **S.C-E.C**: strong contaminate-Extreme contaminate; **E.C**: Extreme contaminate.

Contamination Factor (C.F) :

Contamination Factor was used to calculatethe Contamination level as described in (**Equation 2**).This**Equation**involves dividing metal concentration in the sedimentby thecorresponding background value as reported by **Turekian and Wedepohl, (1961).**

$$C.F = con_{measured} / con_{background} \quad \text{(Eq. 2)}$$

Where ***C.F*** *is contamination factor,* $con_{measured}$ *is the concentration metal in the contaminated soil and* $con_{background}$ *is the background metalconcentration.*

The categories of C.F are described as shown in **Table 02**

Table 02 : Classes of Contamination Factors **Hakanson (1980)**

C.F classes	Degree of contamination
CF < 1	L.C
1 ≤ CF ≤ 3	M.C
3 ≤ CF ≤ 6	C.C
CF > 6	V.C

CF: Contamination Factor; **L.C**: Low contaminate; **M.C**: Moderate contaminate ; **C.C**: Consider contaminate ; **V.C**: Very high contaminate

Enrichment Factor (E.F):

The calculation of the Enrichment Factor was conducted in order to determine the level of soil contaminate and the presence of heavy metals concentration in contaminated soil compared to the uncontaminated one (**Kisku*et al*. 2000)**. As depicted in(**Equation 3**) and evaluating categories were shown in **Table 03.**

$$\mathbf{EF} = \frac{\mathrm{C\,x}}{\mathrm{C\,ref}} sample / \frac{\mathrm{C\,x}}{\mathrm{C\,ref}}\ background (\mathbf{Eq.\ 3})$$

*where **E.F** is enrichment factor,* C_x *is the interest element concentration and* C_{ref} *is the of the normal element, Feconcentration***(Chandrasekaran *et al.*, 2015).**

The average limits of elements concentrate in the soils according to **Alloway (2010)** were used as background.

Table 03: Classes of Enrichment Factor **Duzgoren-Aydin *et al*., (2006).**

EF classes	Degree of contamination
EF < 2	D.M.E
2 ≤ EF < 5	M.E
5 ≤ EF < 20	S.E
20 ≤ EF < 40	V.E
EF ≥ 40	E.E

EF: Enrichment Factor; **DME**: Deficiently to Minimal Enrichment; **ME**: Moderate Enrichment;**SE**: Significant Enrichment; **VE**: Very High Enrichment; **EE**: Extreme High Enrichment.

The Risk Assessment Code (RAC)

Perin*et al.*, (1985),introduced the Risk Assessment Code (RAC) as a means of assessing themovability of heavy metals,the RAC evaluates the ratio of metal concentrate in the F1+F2fractions to the overall concentration (**Equation 4**).Five categories can be distinguished in **Table 04**.

$$\textbf{RAC} = (F1+F2)/(F1+F2+F3+F4+F5) * 100 \quad (\textbf{Eq. 4})$$

*Where **RAC** is the Risk Assessment Code**, F1** is the exchangeable fraction**, F2** is the Associated with carbonate**, F3** is the Associated with organic matter, **F4** is the Associated with Fe-Mn oxide and **F5** is the residual.*

Table 04: Classes of Risk Assessment Code

RAC classes	Risk Assessment Code
RAC < 1	N.R
1 ≤ RAC <10	L.R
10 ≤ RAC <30	M.R
30 ≤ RAC <50	H.R
RAC ≥ 50	V.R

RAC Risk Assessment Code**; N.R**: No risk**; L.R**: Low risk; **M.R**: Medium risk; **H.R**: High risk; **V.R**: Very High risk

Results and Discussions

The soil samples measured parameters were listed in **(annex 1)** andclassified heavy metals into four categories; uncontaminated, Light Contamination, Contamination and High Contamination **FAO,(2006).** Total Cd covered about 0.2%, 93.7. %, 5.7 % and 0.2 % of the studied soil samples, respectively, in soil depth (0-30 cm) of Tamyah district;the corresponding results for the Al-Fayoum district were 0 %, 1.5 %, 9.6 % and 88.8%, respectively.

The value of total Ni ranged between 16 ppm to 88.5 ppm in the-surface layer (0-30 cm), light contamination soil,encompassedan area of 52.1 %, while contamination soil enclosed almost 47.7% in Tamyah district soil samples and about13.3% and 35.3.5% in Al-Fayoum district soil samples, respectively, with appearing of high contamination class cover 50% of Al-Fayoum district soil samples .

As for the levels of Total Pb in upper layer (0-30cm), soil samples in Tamyah and Al-Fayoum districts rangedbetween 10.9 to 35.5 with 20.2 ppm mean value, based on this dataTamyah district soil samples consider uncontimination with Pb in 82% of soil sites and possess contamination in 17.6% of selected sites only. Same indicators found in Al-Fayoum districts soil samples with variation between uncotimination and light contamination which enclosed 44% and 55.9%, respectively, **Figure 02 and Figure 03**.

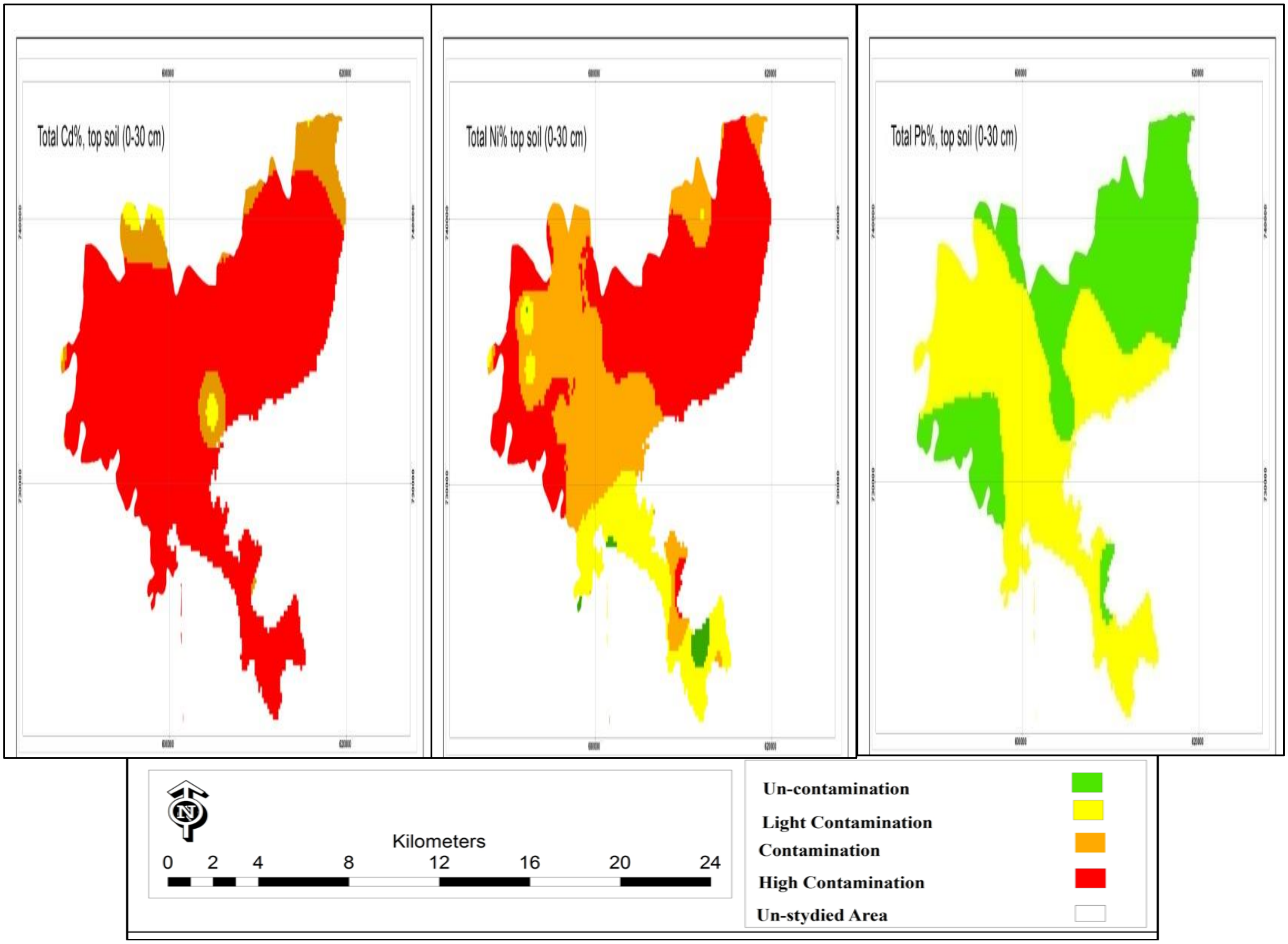

Figure 02: **A** % distribution of soil Cd in samplesof Al-Fayoum district ,**B** % distribution of soil Ni in samplesof Al-Fayoum district , **C** % distribution of soil Pb in samplesof Al-Fayoum district

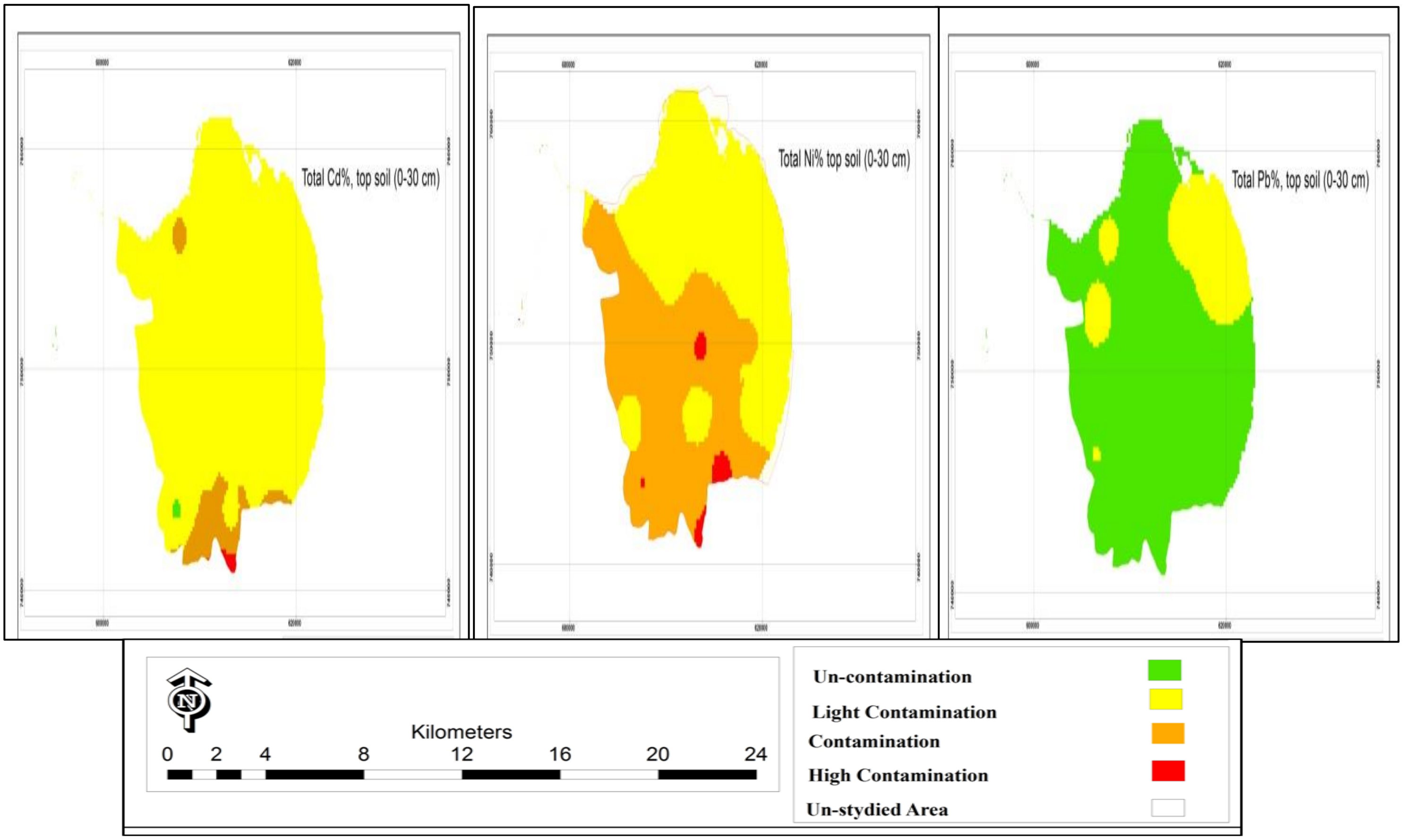

Figure 03: A % distribution of soil Cd in samplesofTamyahdistrict ,**B** % distribution of soil Ni in samplesofTamyah district , **C** % distribution of soil Pb in samplesofTamyah district

These results indicated that concentration of Cd and Ni, were higherthan those of the world soils datasubmitted by **WHO, (1996)**and several countries **Table 05, (Abd El-Aziz2021),**On the other hand,these results showed improved desirable compared to the results of **Abd Elgawad*et al.*, (2007)** whom reported that soils of Fayoum district contain 40.8 ppm Cd and 93.5ppm of Ni. The high concentration may be attributed to the quality of irrigation water, fertilization and also to some specific soil characteristics such as $CaCO_3$ which possesses a direct proportion with Cd**.**Additionally, increase of pH of Al Fayoum Government soils above 7.9, contribute to increasing Cd adsorption in several area**s,**but decreasing the total dissolved concentration of Pb.**(EL-Hassanin*et al*., 2022)** and**(Gu *et al.*, 2022).**Moreover, organic matter recorded variations in the studied soil samples between 0.9 to 2.8ppm, which its phase form relatively strong complexes that haveinsignificant relationship with Pb**,** which not exceeded the allowable limitset byWorld Health Organization and several countries**Zaky and Abdel-Salam** (**2020)**.

Table 05: Critical limits of heavy metals and some soil characteristicsandstudied samples average ranges

Elements	WHO	denmark	Eastern Europe	Germany	Netherlands	Chaina	Tanzania	USA	Studied samplesMin	Studied samplesMax	Studied samplesaverage
Cd	0.8	0.3	2	0.9	0.8	0.4	1	0.4	0.15	4.4	1.61
Ni	35	10	85	15.7	35	50	100	72	16	88.5	42.46
Pb	40	40	32	40-100	85	80	200	200	10.94	35.5	20.23
pH									7.5	8.8	8.1
$CaCo_3$									2.9	30.1	13.6
O.M									0.09	2.81	1.23

Cd: cadmium; **Ni**: Nikel;**Pb**: Lead;**O.M**: Organic matter;**$CaCO_3$**: Calcium Carbonate;**pH**: measure of the acidity or basicity

Soil heavy metals fractionation

Results of soil heavy metals distribution exhibited that the studied soil samples located in the southern part of Tamyah and Al Fayoum districts possessed Contamination and high Contamination for Cd and Ni, Except Pb which recorded light Contamination.

According to these results, Positive correlation coefficients were found between totalCd concentration and each of the electrical conductivity (ECe),pH, calcium carbonate$CaCO_3$, and sand content(r=0.109, 0.244**,0.053 and 0.181* respectively), while negative correlation coefficients were with organic matter, clay and silt contents (r=-.184-*, -0.138 and -0.119, respectively).**(Table 6)**Onthe other hand, total Ni showed negative correlation coefficients with $CaCO_3$, silt and sand contents (r-0.244**, -0.148 and -0.004, respectively), while Pb showed positive correlation coefficients with all soil characteristics.

Based on the previews data, most of Cd concentration is located in southern and middle parts of Al-Fayoum Governorate due to increase of soil pH and $CaCO_3$ values. The second observation was Ni contents, which referred to light contamination to contamination, due to the increase of $CaCO_3$, clay contents and pH value. Finally, normal concentration of Pb was positively correlated with the other soil characteristics **Table 06.**

Table 06: Correlation coefficients between some soil characteristics and heavy metals of the studied samples

	Cadmium	Nickel	lead	ECe	pH	$CaCO_3$	O.M	Clay	Silt	Sand
Cadmium	1									
Nickel	0.656**	1								
lead	0.025	0.021	1							
ECe	0.109	0.074	0.566**	1						
pH	0.244**	0.138	0.068*	-0.067	1					
$CaCO_3$	0.053	-0.244**	0.108	0.046	0.053	1				
O.M	-.184-*	0.001	0.152	0.059	0.027	-.204-*	1			
Clay	-0.138	0.089	0.015	0.073	0.086	-.315-**	0.117	1		
Silt	-0.119	-0.148	0.024	-0.032	0.093	0.140	-0.038	0.049	1	
Sand	0.181*	-0.004	0.014	-0.064	-0.120	0.164	-0.046	-.850-**	-.518-**	1

O.MOrganic matter, ***ECe***Electrical Conductivity, ***pH***measure of the acidity or basicity

Data in **(Table 7)**, detected that the non-residual fraction (F1+F2+F3+F4) that encompasses the metal load resulting from human activities is comparatively more and accessible to plants than the residual fraction,**(Cao, *et al*,. 2018)** it contained averages of Cd 63%, Ni 64.7% and Pb 54.8%

The bio-available categories (F1) and (F2)**,** showedredouble variations among the studied sites**,** for(F1)fraction, where it is the most potentially mobile fraction, available to living organisms and most straightforwardly reach to groundwater **(Gleyzes*et al*,. 2002)**the percentages of Cd, Pb, and Ni were recorded as8.66%, 16 % and 1.1% respectively, lower percentages of Ni can be explained by decreasing sorption with increasing pH.On the other hand, the carbonate fraction (F2) was most important fraction due calcareous nature of El-Fayoum Governorate with $CaCO_3$>5%. (**Salman *et al.*, 2018)**,Thisleads metals to precipitation as carbonates, and appear with strongly associated with Cd in 41.4% of the total studied sites, due to significant correlation with $CaCO_3$ and soil texture **Lotfy, (2000)**.

Regarding the potential bio-available categories (F3+F4) **Nannoni and Protano, (2016),** reported the same ratio of Cd, in the organic fraction (F3) and in Fe/Mn oxides (F4) with value 6.8%,and 6.2%, respectively. While Ni in organic fraction (F3) represented 8.5%, but the highest strongly bound with Ni was found as 53.6%; in Fe/Mn oxides (F4) form which can inter into the environment under oxidizing conditions; finally, Pb possessed values 8.7 %, and 13.7%, respectively.

Furthermore, the residual fraction forms (F5) are bound with crystalline structure, immobilized, and that will not represent a threat to the ecosystem. Their content 20.54%, 35.13% for Cd and Ni, respectively, and mainly bound to Pb with 45.19%. These results verified that residual fraction (F5) controls the distribution of Pb, as it is insignificantly bound with $CaCO_3$but significantly with soil organic matter and with the soil structures according to **Keshavarzi*et al,*.**(**2019)**.

Table 07: heavy metals non-residual fraction, the residual fraction and RAC of the studied samples

No	metal	Heavy metal fraction		(RAC)	No	metal	Heavy metal fraction		(RAC)
		Sum F1+F2+F3+F4	Residual (F5)				Sum F1+F2+F3+F4	Residual (F5)	
1	**Cd**	68.75	30.31	47.32	6	**Cd**	65.80	34.20	52.81
	Ni	74.87	24.60	4.37		**Ni**	46.57	53.43	1.78
	Pb	81.58	18.00	45.67		**Pb**	52.00	47.26	31.32
2	**Cd**	62.22	36.54	55.00	7	**Cd**	60.47	39.53	51.63
	Ni	80.66	19.34	3.38		**Ni**	30.96	69.01	0.39
	Pb	79.22	20.68	47.06		**Pb**	51.40	48.60	28.26
3	**Cd**	54.65	45.35	43.02	8	**Cd**	65.71	34.29	56.43
	Ni	77.36	22.62	0.17		**Ni**	80.65	19.33	3.37
	Pb	45.09	54.71	30.88		**Pb**	54.35	46.62	28.50
4	**Cd**	63.91	34.59	57.25	9	**Cd**	67.33	32.33	40.80
	Ni	44.68	55.30	0.34		**Ni**	77.39	22.61	0.18
	Pb	44.70	55.30	28.25		**Pb**	43.62	56.24	29.28
5	**Cd**	57.30	42.70	47.19	10	**Cd**	64.38	35.62	52.05
	Ni	60.28	38.98	5.99		**Ni**	73.96	26.07	5.46
	Pb	47.00	53.38	26.95		**Pb**	49.08	51.16	26.56

Generally,**Figures 04, 05 and06,**depicted the descending orders of the percentage of the studied heavy metals fractions in the selected soilsites, it was evident that: **Cd** (F2> F5 > F1 > F3 > F4), **Ni** (F4> F5 > F3 > F2 > F1), and **Pb** (F5 > F2 >F1 > F4>F3).

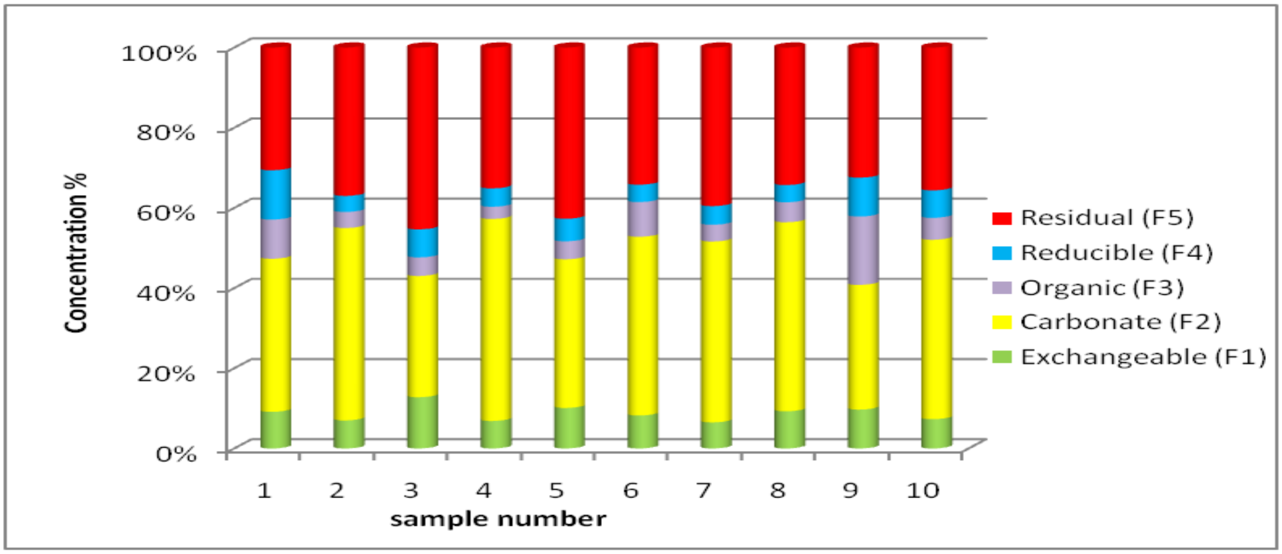

Figure 04 % **Cd** fractions order in study area

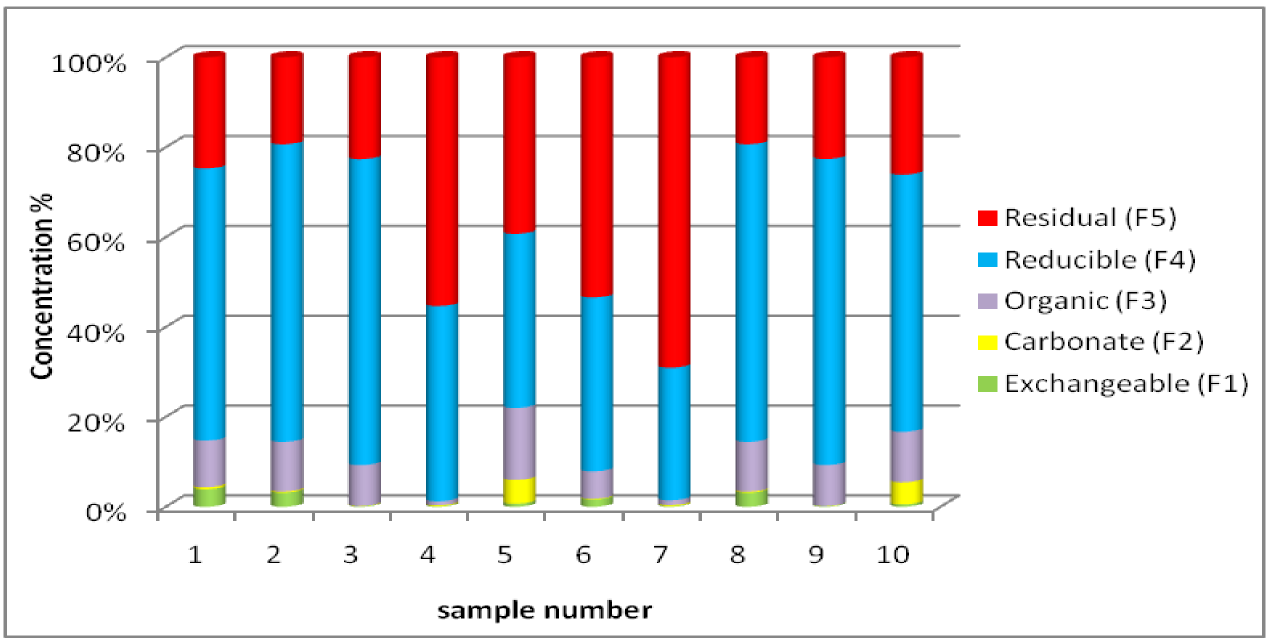

Figure 05 % **Ni** fractions order in study are

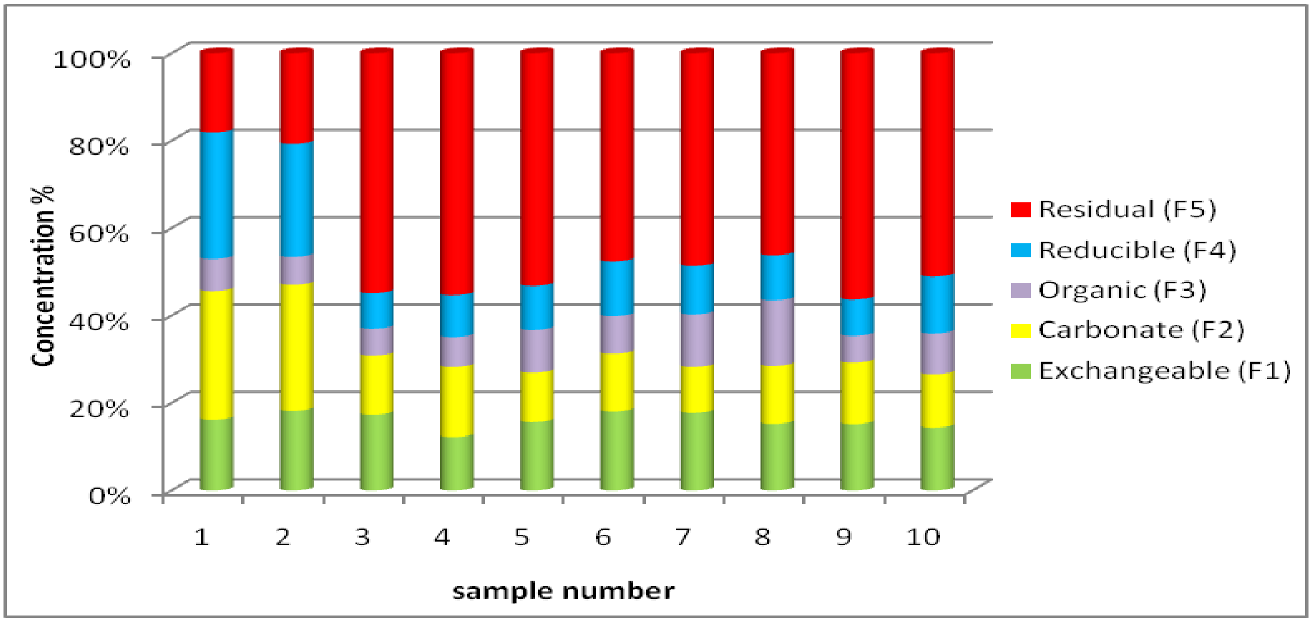

Figure 06 % **Pb** fractions order in study area

Assessment of pollution Indices in Soil

Many pollution indices were used for determinedthe levels of Cd, Ni and Pbcontamination, includingIgeo, EF, CF,RAC and DC (**Ling *et al.*, 2022**).

The Igeo averaged for Cd, Pb and Ni, in studied sampleswere varied between moderately / strong contaminated (class 3), to extremely contaminated (class 6) for all Heavy metals, **(Buccolieri*et al.* 2006) (Table 1).**

Soil samples from Al-Fayoum district were polluted by these metals to a various exten, where Igeo Index values for (Cd**)** showed that categories were from strong to extremely contaminated (classes 4 and 5), appeared only in the investigated soil samples from Al Fayoum district, while thestudied soil samples of Tamyadistricts showed moderately to strong contaminated levels.

Index values for Ni varies between 8.53 and 11.51;thisindicating that it’s an extremely contaminated soil (class 6), This contamination is observed in the soil samples from Al Fayoum and Tamyadistricts, due to increasing amount of Ni greater than the world soils data submitted by **WHO, (1996)**.While(Pb) ranged from 1.84 to 3.56.These values represent that in thestudied sitesof Al Fayoum and Tamya districtshave either Uncontaminated/Moderately contaminated (classes 1 and 2), due to low concentrate of thiselement in the samples. Finally, as depicted in **Figure 07**, I-geo index values followed this order: Ni >Cd >Pb .

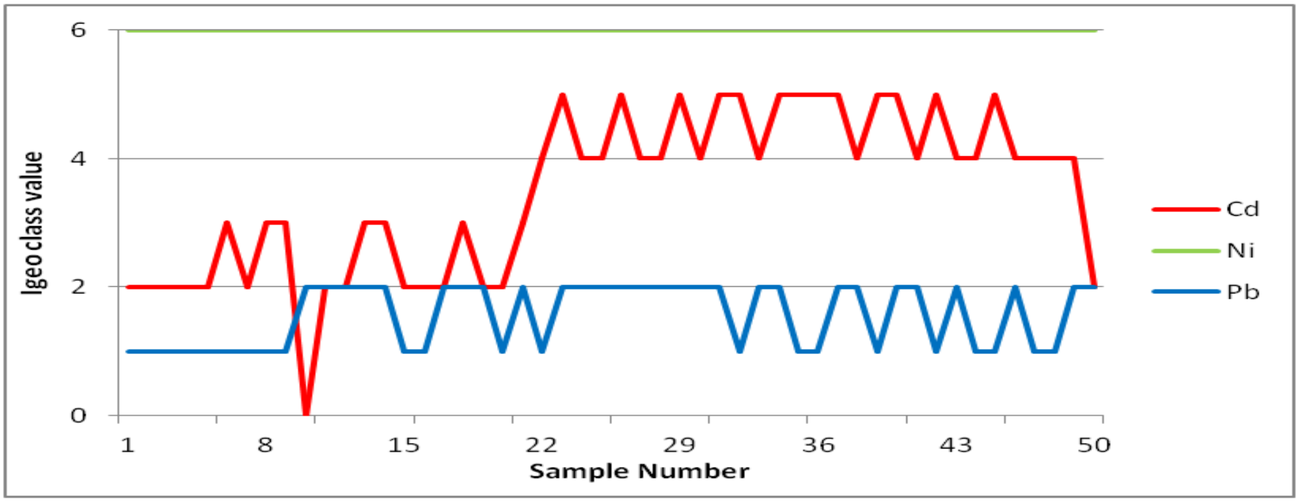

Figure 07: I-geo index values order in study area

Contamination factor (CF) :

According to background values of heavy metals in the crust, contamination factors were calculated for soil samples and given that, the contamination factors for Cd ranged between 0.02 to 14.7 with a very high contamination factorin studied soil samples of Al-Fayoum district,which can be attributed tohigh concentration of this element in the selected samples sites as a result of a direct proportion with increase of pH and $CaCO_3$, while the northern part which include Tamyah, exhibited Low to Moderate contamination factor with an average of 0.02 to 2.97This can be attributed to thedecreasing amount of $CaCO_3$.

Ni contamination factor revealed Considerable contamination as a major class with an average value equals 5 in all soil samples of Tamya district, except site no 12, and Very high contamination class with an average value 6.8 in Al-Fayoum district soil samples, except site 41, while Pb showed the Lower Contamination factors less than 1 in 96% of the study area.

Finally, as shown in **Figure 08,** Contamination factor values for the three metals followed this descending order: Cd >Ni > Pb.

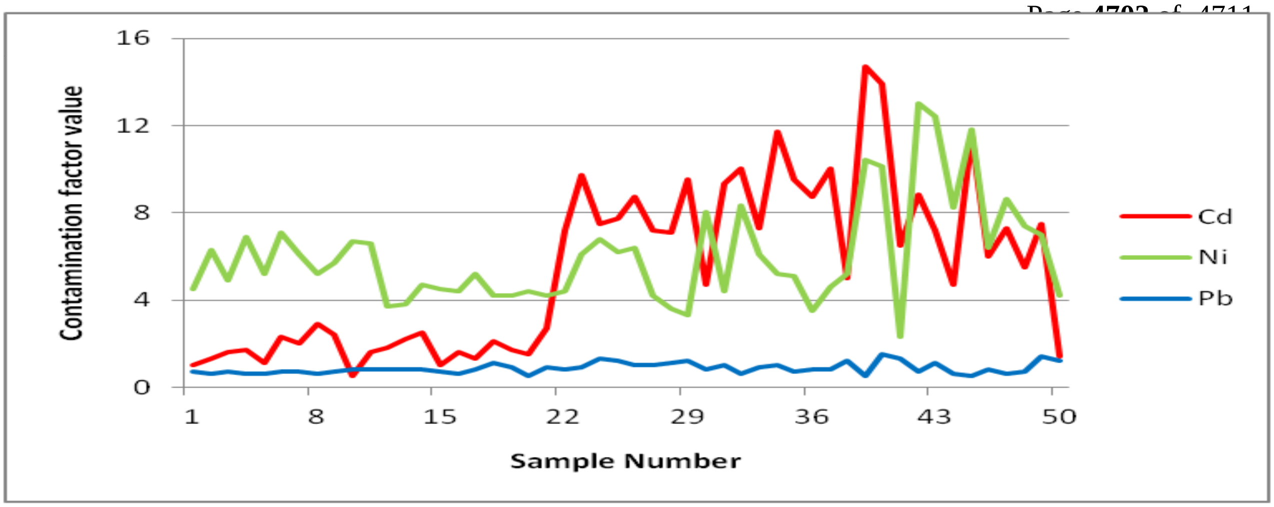

Figure 08: Contamination factors order in study area

Enrichment factor (EF):

Cd value varied betweennorth and south parts, a very high enrichment class with an average value of more than 20, had occupied the soil samples of Al-Fayoum district, a significant enrichment class with values between 5 and 20 covered the north area in Tamyah district, value of Ni enrichment factor among the studied siteswere classified as moderate to a significant with Enrichment Factor value ranged from 2.1 to 13.9, while Pb Enrichment Factor indicated thatall soil sampling sites of Al-Fayoum district possessed a significant enrichment for Pb with an average range of 5 to 15.2.

Generaly, as illustrated in **Figure 09,** Enrichment Factorvalues followed the following descending order: Cd > Pb > Ni

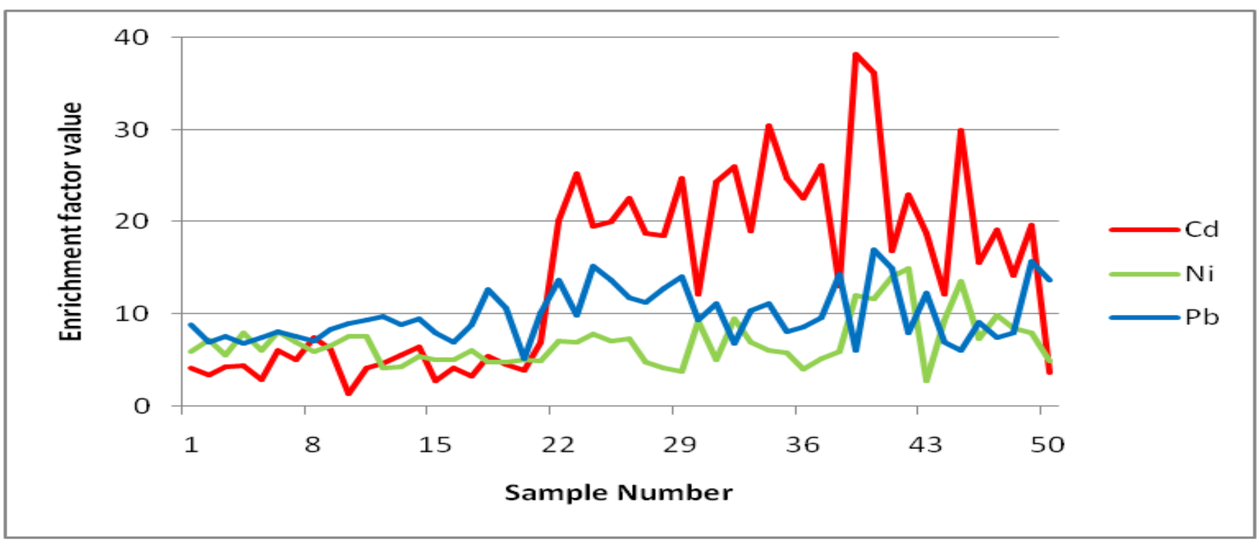

Figure 09 Enrichment factors order in study area

The Risk Assessment Code (RAC)

The bio-available part of metals are consider as exchangeable and carbonate fractions as a result of their weak bonds (**Sundaray*et al*,. 2011).** The Risk Assessment Code is applied by many researchers forevaluates the risk ratio of heavy metals pollution **Kadhum**,**(2022)**

According to (Table4) and (Table7),10 samples were studied to determined the Risk Assessment Code of soil heavy metals and results demonstrate that cadmium was highly mobile in the selected samples as $30 \leq$ RAC <50 as High, in north area in Tamyah district, while very high risk with RAC $\geq$ 50, appeared in Al Fayoum districts, Pb risk consider medium with RAC equivalent $10 \leq$ RAC <30, While Ni show no risk, RAC < 1, in four soil samples , and low risk at the rest of samples with RAC value $1 \leq$ RAC <10**Figure 10,** these results confirm those of, I-geo index values, Contamination and Enrichment Factors.

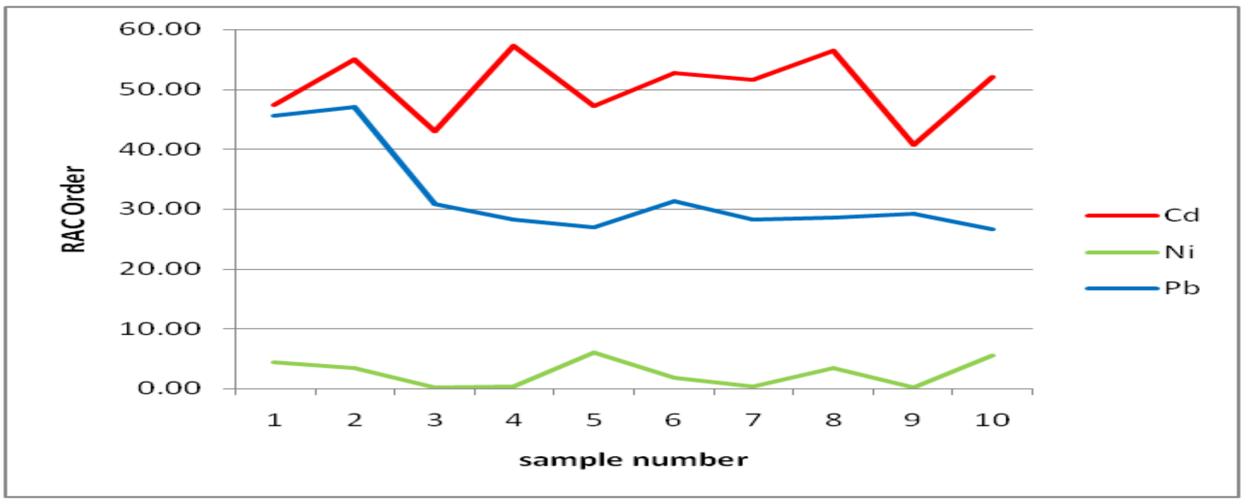

Figure 10 RAC order in the study area

Contamination degree (CD)

According to **Figure 11** the sum of all contamination Heavy metalshow the following result; the studied sites of southern part of Al-Fayoum Governorate has been classified as Considerable contamination between 12 to 24 degree with Cd and moderate contamination with Ni metals, while the the studied sites of northern part of Al-Fayoum Governoratehas been considered moderate contamination between 6 to 12 degree with Cd and Ni, while Pb repossess a low contamination less than 6 degree in all studied sites **Hakanson, (1980).**This result coincides with the distribution andconcentrateof heavy metals, especially Cd and the classified categories of Contamination Factor.

Figure 11 A % Contamination Factors in selected soil samplesof Al-Fayoum district ,
B % Contamination Factors in selected soil samplesofTamyahdistrict .

Conclusion

The present work has studied and monitored the concentrate of three heavy metals cadmium, lead and nickel in some soils of El-Fayoum Governorate,Egypt.The results showed that the levels of heavy metals in the soils were slightly higher than the critical limits set by the World Health Organization (WHO), with cadmium and nickel being of particular concern due to their toxic effects on plants and their presence in the food chain. Lead, on the other hand, was within permissible limits **WHO, (1996)**

The calculation of the geoaccumulation index for the three heavy metals revealed that nickel had high indices, indicating significant accumulation in the soils. However, it is important to note that the geoaccumulation index for nickel was negative in the Risk Assessment Code.

The study also assessed the enrichment factor and contamination factor to determine the level of heavy metal pollution in the area. The results showed that the study area was moderately polluted based on the enrichment factor but strongly polluted based on the contamination factor. This suggests that there is a higher degree of contamination due to elevated levels of heavy metals compared to background values.

Analysis of heavy metal fractionation revealed insights into how these metals are bound in the soil. The majority of cadmium was found in the carbonate fraction, nickel was predominantly associated with Fe/Mn oxides, and lead was mainly present in the residual fraction. Periodic monitoring of heavy metal fractionation is essential to assess their toxicity and availability in agricultural soils.

These results are highlighting the need for ongoing monitoring and management strategies to mitigate heavy metal pollution in agricultural areas

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sample	Cd	Ni	Pb	Igeo class value			Contamination factors			Enrichment factor			Contamination degree
				Cd	Ni	Pb	Cd	Ni	Pb	Cd	Ni	Pb	
1	0.38	35.15	22.85	2	6	1	1.0	4.5	0.7	4.2	5.9	8.9	8.8
2	0.39	42.70	14.43	2	6	1	1.3	6.3	0.6	3.4	7.2	6.9	8.8
3	0.49	33.22	15.89	2	6	1	1.6	4.9	0.7	4.3	5.6	7.6	7.8
4	0.51	46.74	14.20	2	6	1	1.7	6.9	0.6	4.4	7.9	6.8	10.2
5	0.34	35.58	15.42	2	6	1	1.1	5.2	0.6	2.9	6.0	7.4	7.4
6	0.69	48.28	16.84	3	6	1	2.3	7.1	0.7	6.0	8.1	8.1	11.2
7	0.59	41.38	15.82	2	6	1	2.0	6.1	0.7	5.1	7.0	7.6	9.8
8	0.86	35.24	14.86	3	6	1	2.9	5.2	0.6	7.5	5.9	7.1	9.8
9	0.71	38.86	17.59	3	6	1	2.4	5.7	0.7	6.2	6.6	8.4	9.7
10	0.15	45.22	18.85	0	6	2	0.5	6.7	0.8	1.3	7.6	9.0	17
11	0.48	44.83	19.64	2	6	2	1.6	6.6	0.8	4.2	7.6	9.4	10.2
12	0.54	25.06	20.3	2	6	2	1.8	3.7	0.8	4.7	4.2	9.7	7
13	0.65	25.61	18.56	3	6	2	2.2	3.8	0.8	5.6	4.3	8.9	7.6
14	0.75	32.00	19.87	3	6	2	2.5	4.7	0.8	6.5	5.4	9.5	8.2
15	0.31	30.42	16.70	2	6	1	1.0	4.5	0.7	2.7	5.1	8.0	6.6
16	0.47	30.00	14.67	2	6	1	1.6	4.4	0.6	4.1	5.1	7.0	7.3
17	0.38	35.60	18.42	2	6	2	1.3	5.2	0.8	3.3	6.0	8.8	7.8
18	0.62	28.72	26.26	3	6	2	2.1	4.2	1.1	5.4	4.8	12.6	7.8
19	0.52	28.72	22.01	2	6	2	1.7	4.2	0.9	4.5	4.8	10.6	7.7
20	0.45	30.00	10.94	2	6	1	1.5	4.4	0.5	3.9	5.1	5.2	7.1
21	2.90	41.50	20.64	3	6	2	2.7	4.2	0.9	7.0	4.9	10.1	8.6
22	2.13	56.16	26.48	4	6	1	7.2	4.4	0.8	20.2	7.1	13.7	15.7
23	2.31	42.04	28.50	5	6	2	9.7	6.1	0.9	25.2	7.0	9.9	17.9
24	2.61	43.50	24.51	4	6	2	7.5	6.8	1.3	19.5	7.8	15.2	16.3

25	2.15	28.36	23.50	4	6	2	7.7	6.2	1.2	20.0	7.1	13.7	15.2
26	2.13	24.35	26.58	5	6	2	8.7	6.4	1.0	22.6	7.3	11.8	16.8
27	2.85	22.50	29.46	4	6	2	7.2	4.2	1.0	18.7	4.8	11.3	12.9
28	1.40	54.63	19.67	4	6	2	7.1	3.6	1.1	18.5	4.1	12.8	12.6
29	2.80	30.16	23.11	5	6	2	9.5	3.3	1.2	24.7	3.8	14.1	14.9
30	3.00	56.16	14.26	4	6	2	4.7	8.0	0.8	12.1	9.2	9.4	13.8
31	2.19	41.2	21.64	5	6	2	9.3	4.4	1.0	24.3	5.1	11.1	14.9
32	3.50	35.50	23.16	5	6	1	10.0	8.3	0.6	26.0	9.5	6.8	19.1
33	2.85	34.50	16.91	4	6	2	7.3	6.1	0.9	19.0	6.9	10.4	15.5
34	2.60	23.61	17.96	5	6	2	11.7	5.2	1.0	30.4	6.0	11.1	18.1
35	3.01	31.00	20.10	5	6	1	9.5	5.1	0.7	24.7	5.8	8.1	16.2
36	1.51	35.26	29.71	5	6	1	8.7	3.5	0.8	22.6	4.0	8.6	13.4
37	4.40	71.00	12.50	5	6	2	10.0	4.6	0.8	26.1	5.2	9.6	15.7
38	4.16	68.94	35.50	4	6	2	5.0	5.2	1.2	13.1	5.9	14.3	12.5
39	1.95	83.48	31.25	5	6	1	14.7	10.4	0.5	38.2	12.0	6.0	26.5
40	2.65	88.50	16.50	5	6	2	13.9	10.1	1.5	36.1	11.6	17.0	26.4
41	2.15	16.00	25.67	4	6	2	6.5	2.3	1.3	16.9	14.1	15.0	21.1
42	1.40	55.45	14.61	5	6	1	8.8	13.0	0.7	23.0	14.9	7.9	22.7
43	3.45	80.50	12.50	4	6	2	7.2	12.4	1.1	18.7	2.7	12.3	10.9
44	1.80	43.50	19.00	4	6	1	4.7	8.2	0.6	12.1	9.4	7.0	13.7
45	2.20	58.50	15.50	5	6	1	11.5	11.8	0.5	29.9	13.6	6.0	24
46	1.64	50.45	16.62	4	6	2	6.0	6.4	0.8	15.6	7.3	9.1	13.4
47	2.26	47.40	32.66	4	6	1	7.3	8.6	0.6	19.1	9.9	7.4	17.3
48	0.42	28.86	28.64	4	6	1	5.5	7.4	0.7	14.2	8.5	8.0	13.8
49	0.44	41.95	17.82	4	6	2	7.5	7.0	1.4	19.6	8.0	15.7	16.5
50	2.65	88.50	19.00	2	6	2	1.4	4.2	1.2	3.6	4.9	13.7	7.4